



Tutorial Title:

Maritime Electrification — State-of-the-Art Hybrid Power Systems for Green Marine Transport

Organizers:

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Abstract:

Marine sector decarbonization is another battlefield for meeting the goal of climate action and ensuring the fulfillment of ambitions for a zero-emission society. Driven immediately from the policies such as energy efficiency and carbon intensity indicator rating system for ships initiated by The International Maritime Organization (IMO) targeting 50% reduction on the total annual GHG emissions by 2050, and carbon taxation and labeling by European Union, a series of innovations that are centered around marine transportation are emerging from both industry and the academic. These innovations are featured by electrification through advanced power electronic based power systems with various new energy storage systems and low-emission fuels, as well as increased intelligence and efficient control strategies applied to these maritime power systems. This tutorial aims at providing the audience a compact yet comprehensive overview of the advancement of control, operation, and design of typical maritime power systems, the condition monitoring and data analysis for energy storage, as well as relevant industrial advancements. At the same time, several practical case studies will be demonstrated to deepen the understanding of how these new approaches solved the challenges of the current and emerging maritime power systems, and to guide the future analysis and design of more advanced maritime power systems.

The following modules will be covered to address five of the key topics. First, the opportunity and challenge for decarbonization of marine transportation sector will be given, the emphasis will be on the all-electric powertrain based on state-of-the-art power electronics and fed by battery system and alternative fuels.

For the shipboard electrification, the onboard power system will represent itself in the form of microgrids. To coordinate different components, a hierarchical control both in centralized and distributed ways will be introduced in the second module. A case study of onboard microgrid hierarchical control will be given, to walk the audience around how this method can be applied to the onboard power system and the latest advancement in the control and operation will be reviewed.

As the battery will be an indispensable and the costliest component for the emerging electrified shipboard power system as well as advanced ship charging solutions, how to ensure the reliable



operation and extend the lifetime of the energy storage system become a hot topic. The third module will introduce aspects related to Lithium-ion battery performance, degradation, and lifetime. Furthermore, methods for battery lifetime extension and prediction will be covered.

Not limited to onboard microgrids, marine grid is a new concept which deals with the electrification of different energy networks installed in harbors, ports, ships, and various ocean platforms with the involvement of multiple energy flows, i.e., electrical power, fossil fuel, and heating/cooling power. A cross-disciplinary view on this emerging “maritime multi-energy system” will be introduced in the fourth module.

To catch up with the latest advancement of fuel cell developments for shipboard power system, industrial expert from ABB will give a talk covering the topics not only technically but also economics on integrating the fuel cell for the marine vessels.

Bio:

Chendan Li (S'13-M'16) received the B.S. degree from Nanjing Agricultural University, Nanjing, China, in 2009, the M.S. degree from the Nanjing University of Aeronautics and Astronautics, Nanjing, in 2012, both in electrical engineering. She got her Ph.D. degree in Aalborg University, Denmark, in 2016 in Analysis and Control for AC and DC Microgrids. She was a Post-Doctoral Fellow in Department of Electric Power Engineering at The Norwegian University of Science and Technology (NTNU) while she worked on smart distribution systems and now work as a researcher for marine electrification in the department of Marine Technology NTNU. She serves as an associate editor on the editorial board for Electrical Engineering, Springer and has given several talks in the conference including the plenary talk for ISGT Europe 2021 about her research. Her main research interests include analysis and control for AC and DC microgrids, including onboard microgrids, operation of distribution system, stability for power electronics based power systems.

Mehdi Zadeh received the Ph.D. degree in electrical engineering from Norwegian University of Science and Technology (NTNU), Trondheim, Norway, in 2016. From 2016 to 2017, he was with the power electronics industry, working on the development of battery charging systems. In 2017, he joined the Marine Technology Centre at NTNU in Trondheim, where he is currently an Associate Professor of Hybrid Power Systems and the director of the Marine Electrification Research Lab. His main research interests include ship electrification for low-emission and autonomous shipping, onboard DC power systems, and offshore renewable energy systems.

Sidun Fang received his B.E degree and Ph.D. degree in Chongqing University and Shanghai Jiao Tong University, respectively in 2012 and 2017. Now he is a full professor (Hongshen Young Scholar program) with the School of Electrical Engineering, Chongqing University. His research interest is the Integrated Transportation and Energy systems, especially in maritime applications. Dr. Fang was awarded the Outstanding Graduate prize of Shanghai Jiao Tong University and his doctoral dissertation was nominated as Excellent Dissertation Papers in Shanghai Jiao Tong University in 2017. He has published one book in Springer Nature and more than 30 journal



papers as the first author Since 2015. Dr. Fang is an editor for IEEE Transactions on Industry Applications and International Transactions on Electrical Energy Systems.

Daniel Stroe received the Dipl.-Ing. degree in automatics from “Transilvania” University of Brasov, Romania, in 2008, and M.Sc. degree in wind power systems from Aalborg University (AAU), Aalborg, Denmark, in 2010. He has been with Aalborg University since 2010, from where he obtained his Ph.D. degree in lifetime modelling of Lithium-ion batteries in 2014. Currently, he is an Associate Professor with AAU Energy, where he leads the Batteries research group and the Battery Systems Testing Lab. He was a Visiting Researcher with RWTH Aachen, Germany, in 2013. He has co-authored 1 book and over 150 journal and conference papers in various battery-related topics. His current research interests are in the area of energy storage systems for grid and e-mobility, Lithium-based batteries testing, modelling, diagnostics and their lifetime estimation. He has organized battery and lectured over 10 tutorials in various battery-related topics at among other ECCE-US 2015 and 2018, PCIM Europe 2019, EPE ECCE Europe 2018, 2019, and 2021 etc.

Ahmed Abdelhakim (IEEE SM’19) was born in Egypt on April 1, 1990. He received the B.Sc. and the M.Sc. degrees (with Hons.) in electrical engineering from Alexandria University, Egypt, in 2011 and 2013 respectively, and the Ph.D. degree from the University of Padova, Italy, in 2019. He is with ABB research Sweden since August 2018, where he held several roles, and currently he is a Principal Scientist and R&D project manager since February 2022.

In 2017, he was with the Department of Energy Technology, Aalborg University, Aalborg, Denmark, as a visiting scholar for ten months, where he was working on several research activities. From 2011 to 2014, he was a Demonstrator and then a Lecturer Assistant in Alexandria University. His major field of interest includes power electronics converters and their applications for energy storage and hydrogen systems, investigation of new power converter topologies, and application of wide-bandgap semiconductor devices for high frequency and high-power density power converters.

Dr. Abdelhakim has received first classified excellent Ph.D. dissertation award from Società Italiana di Electronica (SIE’19) among Italian universities in 2019. He is also serving as an Associate Editor with IEEE Transaction on Industrial Electronics and IEEE Transaction on Transportation Electrification.